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Adaptive Watermark Detection Algorithm Using Perceptual Model and Statistical Decision Method Based on Multiwavelet Transform

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ABSTRACT

This paper is proposed a watermarking technique for copyright protection of multimedia contents. We proposed adaptive watermark detection algorithm using stochastic perceptual model and statistical decision method in DMWT(discrete multiwavelet transform) domain. The stochastic perceptual model calculates NVF(noise visibility function) based on statistical characteristic in the DMWT. Watermark detection algorithm used the likelihood ratio depend on Bayes' decision theory by reliable detection measure and Neyman-Pearson criterion. To reduce visual artifact of image, in this paper, adaptively decide the embedding number of watermark based on DMWT, and then the watermark embedding strength differently at edge and texture region and flat region embedded when watermark embedding minimize distortion of image. In experiment results, the proposed statistical decision method based on multiwavelet domain could decide watermark detection.

Keywords: Multiwavelet transform, Statistical decision, Adaptive watermark detection algorithm

1. INTRODUCTION

Today many techniques of the digital watermarking were developed for the copyright protection of multimedia contents. In these digital watermarking systems, one of the important requirements of watermark embedding systems is to compromise between the invisibility and robustness of the embedding algorithm[1].

Voloshynovskiy *et al.*[2] proposed an adequate stochastic modeling for content adaptive digital image watermarking. Knowing stochastic models of the watermark and the host image, one can formulate the problem of watermark estimation /detection according to the classical MAP (maximum a posteriori probability) and stochastic models and estimate the capacity issue of the image watermark scheme. Podilchuk *et al.* [3] developed a content adaptive scheme, where the watermark is adjusted for each DCT block and wavelet domain. This approach is very limited the practical applications since it can be shown that the usage of the cover image will results in watermark schemes which can be easily broken. Kwon *et al.*[4] proposed a highly reliable watermark detection algorithm using statistical decision method based on DWT. This approach detected fixed watermark embedding strength and embedding number. The likelihood

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ratio has a superior distinguishable ability was used by measure of watermark detection at detection algorithm.

In this paper, we proposed the watermark embedding method using JND(just noticeable difference) characteristic and stochastic perceptual model and then the watermark detection method using statistical decision of embedded watermark. The watermark of the proposed statistical decision method is detected adaptive embedding number based on DMWT. Watermark detection algorithm used the likelihood ratio depend on Bayes' decision theory by reliable detection measure and Neyman-Pearson criterion. The proposed watermark detection method in the multiwavelet domain could decide more correctly than statistical decision method in the DWT.

2. WATERMARK DETECTION ALGORITHM

2.1 Watermark Embedding

To embed watermark, we use stochastic perceptual model that calculate NVF based on statistical characteristic in the DMWT. The DMWT is an advantage, since it offers simultaneous compactly support, orthogonality, symmetry, and vanishing moments. Its system can simultaneously provide perfect reconstruction (orthogonality), good performance at the boundaries (linear-phase symmetry), and high order of approximation (vanishing moments). The perceptual model with adaptive watermark embedding algorithm embed watermark to the texture and edge region for more strongly embedded watermark by the JND In the case of stationary Generalized Gaussian model, NVF can be written in the eq. (1)[2]:

$$NVF(i,j) = \frac{w(i,j)}{w(i,j) + \sigma_x^2(i,j)} \tag{1}$$

Where, $\sigma_x^2(i,j)$ denotes the variance of image and $w(i,j)$ denotes weight. The block diagram of proposed method is represented in Fig. 1.

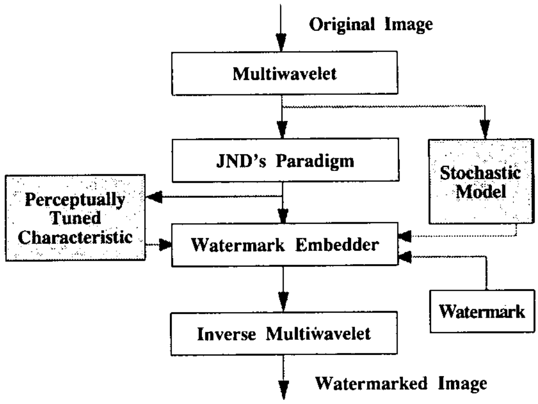

Fig. 1. Block diagram of proposed embedding method.

The multiwavelets decomposed the original image into 4 levels. And then PSCs(perceptual significant coefficients) is founded by the JND threshold of each subband using the Table 1. The JND thresholds determined by a model of human visual system and local image characteristics[4]. Watermark is embedded the selected PSCs.

This threshold defines PSCs in each subband about level and orientation. The final equation with proposed adaptive watermark embedding is following the eq. (2):

$$v' = v \times [1 + \{(1 - NVF) \cdot \alpha_1 + NVF \cdot \alpha_2\} w_i] \tag{2}$$

where v', v, and w_i denote the watermarked image, original image, and watermark. NVF uses mathematically calculated values using eq. (1).

α_1 denotes the watermark strength of texture and edge regions. α_2 denotes the watermark strength of flat region. α_1 is used 0.3 because of considering the error of integrated function by

Table 1. Threshold to select PSCs in each subband.

Orientation \ Level	2	3	4
HL	14.685	12.707	14.156
LH	14.685	12.707	14.156
HH	28.408	19.540	17.864

linear approximation, invisibility and robustness and α_2 is used 0.1 for reducing distortion.

2.2 Detection Algorithm Using Statistical Decision Method

Watermark detection algorithm proposed by Kwon et al.[5] used the likelihood ratio depend on Bayes' decision theory by reliable detection measure and Neyman-Pearson criterion. It is for selection of decision threshold that can minimize decision error. The proposed detection algorithm is achieved multiwavelet domain. The likelihood ratio needs the PDF(probability density function) of DMWT coefficients. The distribution of DMWT coefficients is very similar to a Gaussian distribution, therefore, it is adopted as the PDF of DMWT coefficients. The proposed watermark detection algorithm is represented in Fig 2.

Where, watermark space is composed of W_1 space of including watermark w^* and W_0 space of not including watermark w^*. And $f_x(x)$ express PDF of MDWT coefficients x. $f_y(y|w)$ express the conditional PDF of y for x. $\delta(y)=0$ express that the specification watermark w^* is absent in the test signal y and $\delta(y)=1$ express that the specification watermark w^* is present in the test signal y. Fig. 3 is the block diagram that display decision rule in Fig. 2.

Based on the statistical decision method, the proposed detection scheme verifies whether a given watermark is present in an image using Bayes' decision theory. In Bayes' decision theory used to establish the decision rule, the likelihood ratio needs the PDF(probability density function) of DMWT coefficients. The distribution of DMWT

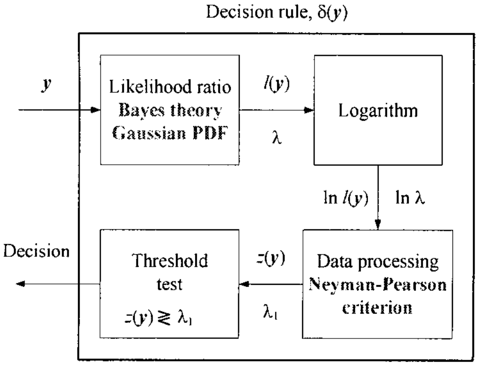

Fig. 3. Flowchart of proposed decision rule.

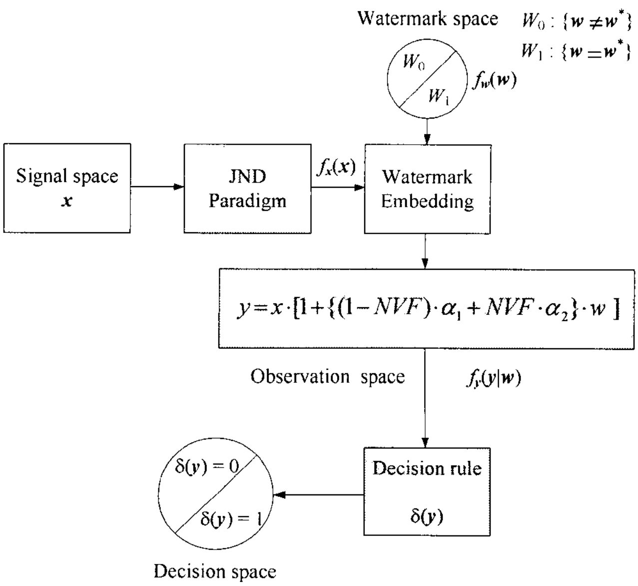

Fig. 2. Watermark detection algorithm.

coefficients is very similar distribution property to a Gaussian distribution, therefore, PDF of DMWT coefficients becomes modeling as a Gaussian distribution. The likelihood ratio $l(y)$ by Bayes' decision theory is same eq. (3). For simply a representation eq. (3) achieve logarithm both direction. The log likelihood ratio $\ln l(y)$ is represented eq. (4). Decision threshold compared with the log likelihood ratio is represented $\ln \lambda$. Here, $z(y)$ and λ' is represented eq. (5) and eq. (6).

$$l(y)=\prod_{i=1}^{N}\frac{1}{(1+\alpha w_i^*)}\exp\left[\frac{(y_i-m_i)^2}{2\sigma_i^2}-\frac{\{y_i/(1+\alpha w_i^*)-m_i\}^2}{2\sigma_i^2}\right] \tag{3}$$

$$\ln l(y)=\sum_{i=1}^{N}\left[\frac{(y_i-m_i)^2}{2\sigma_i^2}-\frac{\{y_i/(1+\alpha w_i^*)-m_i\}^2}{2\sigma_i^2}\right]-\sum_{i=1}^{N}(1+\alpha w_i^*) \tag{4}$$

Also to minimize the missed detection probability subject to a given false alarm probability, the Neyman-Pearson criterion is included in the threshold selection.

$$z(y)=\sum_{i=1}^{N}\frac{1}{2\sigma^2}\left[(y_i-m_i)^2-\left(\frac{y_i}{1+\alpha w_i^*}-m_i\right)^2\right] \tag{5}$$

$$\lambda' = 4.24\sqrt{2\sigma^2_{z(x)}}+m_{z(x)} \tag{6}$$

Where, m_i and σ_i^2 is represented mean and variance of DMWT coefficients in the each subband which x_i is situated. y_i is coefficients that watermark is embedded. $m_{z(x)}$ and $\sigma^2_{z(x)}$ is represented mean and variance of PDF about x_i.

$$\delta(\mathbf{y})=\begin{cases}1, & z(y)>\lambda' \\ 0, & \text{otherwise}\end{cases} \tag{7}$$

Therefore decision rule with the proposed watermark detection algorithm decide whether watermark is present as compare $z(y)$ with λ'.

3. EXPERIMENTAL RESULTS

To illustrate the main features of the proposed adaptive watermark detection, we simulated our algorithm on several images of 512×512 size such as Lena, Baboon etc. First, DMWT decomposed the original image into 4 levels. PSCs are founded by threshold of each subband using the Table 1. And then NVF of DMWT coefficients is calculated by stationary Generized Gaussian model.A watermark is embedded a selected PSCs using calculated NVF and different embedding strength at edge and texture region and flat region.

Fig. 4 and 6 represent original and watermarked image of Lena and Baboon. It showed no visible artifact, because watermark is embedded to be transparent. Fig. 5 represents the selected PSCs. We are able to confirm that watermark was embedded at the edge and texture region stronger than flat one.

The proposed statistical decision method based on DMWT compare with watermark detection method using statistical decision method as

Fig. 4. The original image of Lena and Baboon.

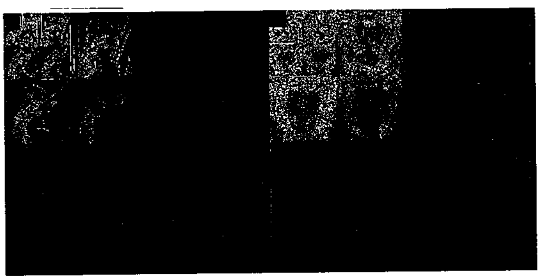

Fig. 5. The selected PSCs.

PSNR=40.14[dB] PSNR=39.02[dB]

Fig. 6. Watermarked image.

embedding 5,000 watermarks into fixed embedding strength based on DWT. To establish the robustness of the watermarked image against lossy compression, JPEG coding with a quality factor varying 10% to 90% was performed and the resultant likelihood ratio are shown in Fig. 7 and 8.

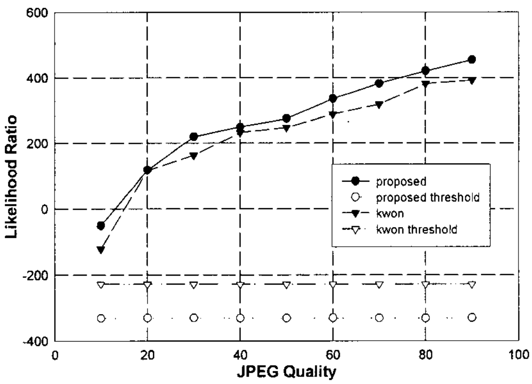

Fig. 7. Likelihood ratio of Lena image.

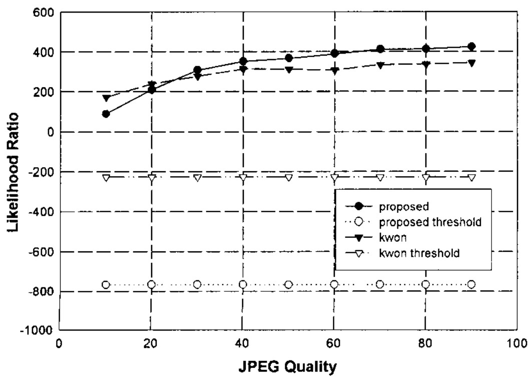

Fig. 8. Likelihood ratio of Baboon image.

To establish the robustness of the watermarked image against cropping attack, cropping ratio varying 10% to 90% was performed and the resultant likelihood ratio are shown in Fig. 9 and 10.

The likelihood ratioof the watermarked image with Gaussian attack, sharpening attack, median filtering, and frequency mode Laplacian removal (FMLR) attacks are shown in Table 2 and 3.

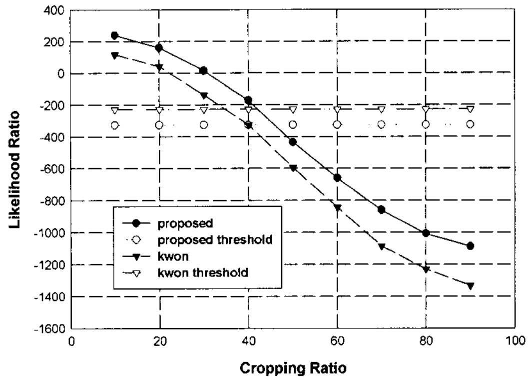

Fig. 9. Likelihood ratio of cropping attack of Lena image.

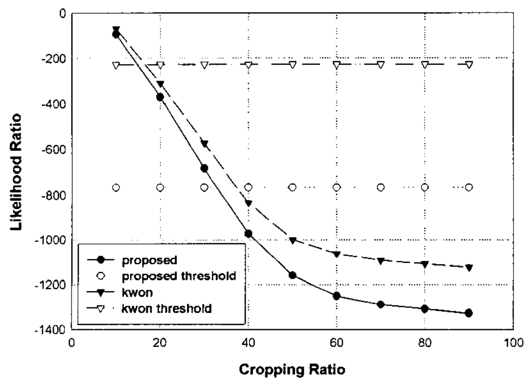

Fig. 10. Likelihood ratio of cropping attack of Baboon image.

Table 2. General image processing of Lena image.

Filtering	Threshold		Likelihood ratio	
	proposed	kwon	proposed	kwon
Gaussian Filtering	-326.98	-227.49	186.42	144.45
Sharpening	-326.96	-226.68	690.08	493.71
Median Filtering	-327.03	-227.63	199.23	86.56
FMLR	-327.78	-226.91	168.41	201.34

Table 3. General image processing of Baboon image.

Filtering	Threshold		Likelihood ratio	
	proposed	kwon	proposed	kwon
Gaussian Filtering	-766.06	-226.74	244.60	192.49
Sharpening	-765.68	-226.60	232.05	62.80
Median Filtering	-765.89	-226.46	294.19	262.50
FMLR	-766.19	-226.78	414.29	385.55

4. CONCLUSIONS

In this paper, we have proposed watermark embedding scheme using adaptive watermark strength in each subband applying NVF.Multi-wavelet coefficient that watermark is embedded selected PSC according to JND property. In order to determine the optimal NVF, we used stochastic multi-resolution property according to a stationary Generalized Gaussian model. Watermark detection could detect exactly by stochastic approach that detect watermark that is embedded in target sign. The experimental results of the proposed scheme were found to be good invisibility and we were able to found more exactly watermark detection than stochastic approach in wavelet transform domain about various kinds attack.

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